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POPULATION STATUS AND REPRODUCTIVE PERFORMANCE OF EURASIAN GRIFFONS (*GYPS FULVUS*) IN EASTERN SPAIN

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Abstract.—The Eurasian Griffon (*Gyps fulvus*) has experienced a measurable increase in population numbers in the Iberian Peninsula and, particularly, in the Castellón province during the last two decades. In Castellón, we have located 18 breeding colonies on a 6670 km^2 area in 2002. These included two new nesting colonies, expanding the known distribution in the province by 64 km^2. The breeding success was 0.83 chicks/laying pair, productivity was 0.66 chicks per detected pair, and the percentage of pairs initiating breeding activities was 79.5%. Two variables were included in the logistic model that best explained the probability of raising a chick successfully (type of nest and its interaction with orientation). The probability of nest success increased with nests located inside caves and with nests located on open ledges that were oriented to the south. There was a significant relationship between the distance to the nearest-neighbor nest with the nest success (0 or 1) in the logistic-regression analysis.

We suggest that conservation of native fauna is necessary to maintain the griffon population in the province. The reduction and closure of vulture restaurants in existing range may have also stimulated southward dispersal of griffons searching for new trophic resources.

Key Words: *Eurasian Griffon;* Gyps fulvus; *breeding success; coloniality; productivity; vulture restaurants; Spain.*

ESTATUS POBLACIONAL Y PARAMETROS REPRODUCTORES DEL BUITRE LEONADO *GYPS FULVUS* EN EL ESTE DE ESPAÑA

Resumen.—Durante las últimas dos décadas, el buitre leonado *Gyps fulvus* ha experimentado un considerable aumento de su tamaño poblacional en la Península Ibérica, especialmente en la provincia de Castellón. En esta provincia hemos localizado un total de 18 colonias de reproductivas en un área de 6670 km^2 en 2002. Dos nuevas colonias de cría no se habían citado previamente, y suponen una expansión de 64 km^2 de la distribución conocida de la especie en la provincia. El éxito reproductivo fue de 0.83 pollos/huevo, la productividad de 0.66 pollos/pareja y el 79.5% de las parejas iniciaron actividades de reproducción. El modelo logístico que mejor explicó la probabilidad de criar un pollo con éxito incluyó dos variables significativas: el tipo de nido y su interacción con la orientación. Los nidos emplazados en cuevas, así como los ubicados en repisas abiertas orientadas hacia el sur, mostraron mayor probabilidad de éxito. Se encontró una relación significativa en el análisis de regresión logística entre la distancia al nido vecino más próximo y el éxito de cada nido (0 ó 1). Sugerimos que la conservación de la fauna silvestre es necesaria para mantener las poblaciones de *G. fulvus* en Castellón. La reducción y cierre de muladares podría haber estimulado la dispersión de los buitres hacia el sur en busca de nuevos recursos tróficos.

[Traducción de los autores]

The large growth in the Eurasian Griffon (*Gyps fulvus*) population in the Iberian Peninsula has been well documented since the 1970s (Errando et al. 1981, Donázar 1987, Arroyo et al. 1990, Donázar and Fernández 1990). The recent national censuses showed increases in breeding pairs of 135% between 1979–89 and 130% from 1989–99 (Del Moral and Martí 2001). In the Castellón province, this growth has been constant and greater (>150%) than the national mean (Del Moral and Martí 2001). In spite of this growth, expansion of griffon distribution both on a national and a local level has not occurred (Arroyo et al. 1990, Donázar 1993, Del Moral and Martí 2001). Conspecific attraction to nest places (Sarrazin et al. 1995) seems to be among the causative factors for this pattern.

In this paper, we present results related to the population status, reproductive performance (breeding success and productivity), and range expansion for the Eurasian Griffon in the Castellón

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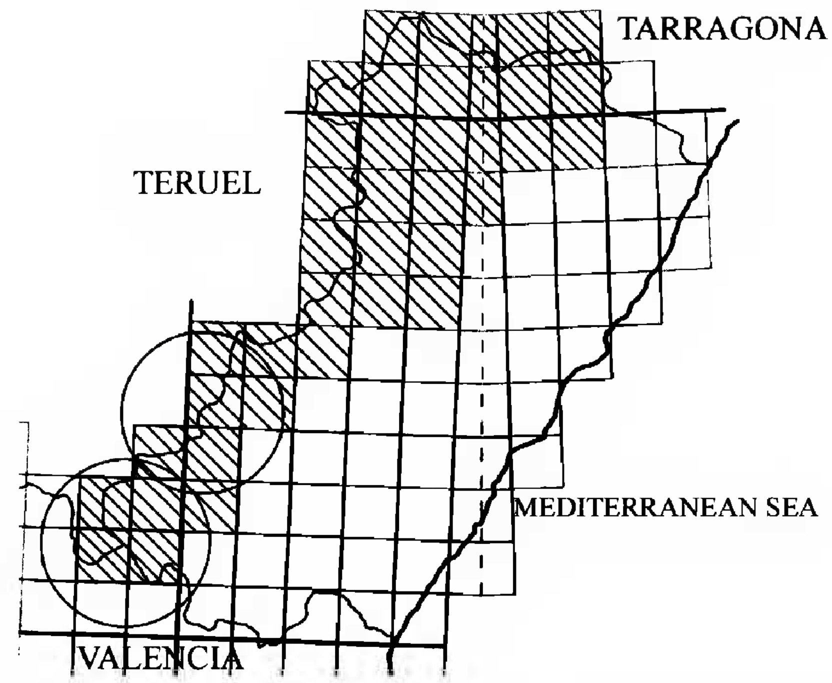

Figure 1. Left: Iberian Peninsula. The shaded area shows the study area, Castellón province. Right: study area general map with Universal Transverse Mercator 10 × 10 km squares. Shaded area squares show frequent Eurasian Griffon presence. Circles indicate the two new breeding colonies.

province. Age of breeding pairs, type of nest, nest orientations, and distance to nearest conspecific nest were recorded and statistically related to nest success. We also provide an analysis of the physical variables recorded at griffon colonies and their relationship with reproductive performance.

STUDY AREA

The study area comprises the Castellón province (Fig. 1; located in the east of the Iberian Peninsula), including 6670 km^2; 40°47′N, 39°42′S, 0°51′W, 0°32′E; 0–1814 m above sea level (masl). The area is geomorphologically characterized as the confluence of two mountain ranges: the Iberian system, oriented northwest-southeast on the one hand, and the east-northeast-oriented structures of the Catalánides, parallel to the coastline. This results in a subtabular and a folded-peak line with calcareous material, mostly sedimentary, which supports many cliffs and walls suitable for the nesting of the griffon. Climatologically, it belongs to the Mediterranean area, with an annual mean temperature varying between 17°C in the coast area and 8°C in the inner highlands (where the entire griffon population is located). The annual mean precipitation varies from 400–900 mm, with maximum values during the fall and minimum values in the summer, characterized by the great interannual irregularity of the Mediterranean weather (Quereda et al. 1999). Bioclimatologically, the study area supports an assortment of vegetation types and ecosystems (Rivas-Martínez 1987). This heterogeneity also manifests itself locally, alternating cultivation zones both irrigated and nonirrigated with forest patches dominated by pines (*Pinus* spp.) and, to a lesser extent, oaks (*Quercus* spp.) and *Juniperus* spp.

The livestock industry in the study area is mainly restricted to intensive feed-lot farms, in which animals are confined and not available to vultures (CAPA 1999). Pasture grazing does occur in the northern regions, the only area where a griffon population has existed for the last 30 yr (Arroyo et al. 1990, Urios et al. 1991, Del Moral and Martí 2001). The livestock is mainly porcine (92.44%), followed in importance by ovine (3.96%), and bovine (2.35%). The availability and use of wild ungulates as a trophic resource for griffons is unknown. Also in the study area, a small number of "vulture restaurants" are scattered in the central part of the province which are available to griffons. "Vulture restaurants" are traditional places close to villages where shepherds and farmers drop carcasses and serve as supplementary feeding sources for carrion-eating birds.

METHODS

We monitored the reproductive success of 112 breeding pairs from December 2001–June 2002. All areas where breeding by griffons was known were observed, as were cliffs larger than 40 m in height with suitable ledges that could be colonized by nesting vultures (Donázar 1993). For the latter, we monitored 85% of the potential nesting cliffs, thus may have missed an isolated-reproductive pair. The coastal area, which has high human density and is less suitable for nesting vultures, was surveyed less intensively; 60% of the potential nesting cliffs surveyed. In the interior areas, we monitored 98% of the potential nesting cliffs.

Observations were made with a 20–60× telescope during clear days and >300 m from nesting cliffs to avoid disturbance to vultures (Fernández et al. 1996, Olea et al. 1999, Gil-Sánchez 2000). At least three visits, in some cases five, were made to every reproductive colony. A preliminary search was made between 20 December and 10 January, in which nuptial flights and copulations were observed (Donázar 1993). The first visit was made between 16 February and 23 February, in which a sketch of the cliff that hosts the colonies was made, noting the locations of pairs and nests. The second visit was made between 21 March and 3 April to confirm the presence/

Table 1. Physical variables recorded at Griffon Vulture colonies (N = 16 colonies).

NAME	DESCRIPTION
Cliff height	Cliff height (m); 1:10 000 digital map.
Distance to top of cliff	Distance (m) from the highest nest to the top of cliff; digitally treated images based on known-length segments previously measured on the field. Recurring measures were only counted once (Olea et al. 1999).
Distance to base of cliff	Distance (m) from the lowest nest to the base of cliff; digitally treated images.
Distance from nearest colony	Distance (m) from nearest colony; 1:50 000 Spanish Army Cartographic Service.
MASL	Mean elevation (m) above sea level; 1:50 000 Spanish Army Cartographic Service.
Distance to nearest nest[a]	Distance (m) to nearest neighbor nest in the same colony; digitally treated images.

[a] N = 82 nests were measured; we could not obtain an adequate digital picture to measure distances accurately at colony No. 13.

absence of the previously-detected pairs, the existence of new nests, and the newly-hatched chicks. Our third visit took place between 19 April–11 May to monitor the development of previously-detected chicks and the presence of new hatchings. Finally, a fourth visit was made in the period between 21 May and 25 June, when 11 of the 18 known colonies were visited. During this last visit, breeding success was recorded, as was the presence of late broods. Those cliffs where the species was not detected during the first two visits were not visited subsequently (Martínez et al. 1997, Del Moral and Martí 2001).

A pair was considered as a laying pair if it was building a nest, incubating, and the griffons were taking turns in the nest, or if typical pair behavior, such as close contact with mutual preening, was observed (Donázar and Fernández 1990, Blanco and Martínez 1996, Olea et al. 1999). A cliff was considered as a colony if it was occupied by at least two pairs and was at least 1000 m away from its closest neighbor, according to the methodology used in the species' 3rd Spanish National Census (Del Moral and Martí 2001). These criteria were modified for two of the colonies because of the more rugged orography of the terrain and its different abiotic characteristics; at these sites we reduced the nearest-neighbor criterion to 600 m. Information gathered for each nest included its orientation and type of location (open ledge, sheltered ledge, or cave). Orientation was measured on the Valencian Cartographic Institute computer-cartographic database to a 1:10 000 scale. For each pair, age was recorded according to plumage (subadult or adult). Those individuals with brown ruff and non-nacreous bill were considered subadults (Donázar 1993, Blanco and Martínez 1996). The following reproductive laying-pair combinations were found: adult-adult, adult-subadult, and subadult-subadult pairs. Selected physical parameters of cliffs were also derived from the cartographic database (Table 1).

The following reproductive parameters were calculated for each breeding colony and for the entire study area: productivity = fledged chicks/detected pairs; breeding success = fledged chicks/laying pairs (Del Moral and Martí 2001). A chick was considered as fledged if, given its development level during the last visit, it was older than 70 d (Del Moral and Martí 2001). Based on the locations of nesting colonies, we calculated a minimum convex polygon to estimate the area in the province occupied by breeding Griffon Vultures (Olea et al. 1999)

Statistical Analysis. Descriptive statistics were calculated for the most variables: productivity, breeding success, cliff height, distance to base of cliff, distance to top of cliff, distance from nearest colony, and masl. We used linear regressions (Sokal and Rohlf 1981, Draper and Smith 1998) with productivity and breeding success of each colony as dependant variables to examine the influence of measured variables on reproductive performance. Finally, in order to assess the relationships between a dependant (response) factor (each nest's success: 0 or 1) against the independent (explanatory) categorical predictors: orientation, type of pair, type of nest, and distance to nearest nest, a logistic regression analysis was performed (Sokal and Rohlf 1981, Fernández et al. 1996, Everitt and Dunn 2001). To employ this method, we used the link function in the generalized-linear models procedure of SPSS (1998), where the predicted variable was logistically transformed (Agresti 1990, Everitt and Dunn 2001). We assumed a binomial distribution of errors and each nest was considered as one case. Standard-stepwise backward procedure was used, including all variables and then removing not significant variables by Wald's method (Johnson 1998, McNally 2000). If the Wald statistic was significant then the parameter was included in the model. We selected the last significant model that included the fewest variables. All calculations were made using the SPSS v11.5 (SPSS Inc. 1998).

RESULTS

We located 16 colonies and two isolated nests in the study area, with 89 laying pairs and 112 detected pairs. Productivity was 0.66 chicks per detected pair (N = 112) and breeding success was 0.83 chicks per laying pair (N = 89). The mean number of visits per colony was 3.22 (SD = 0.88,

Table 2. Generalized linear models for nest success (0 or 1) of Eurasian Griffon, using binomial error and logistic links. Significant model (χ^2 = 25.33, df = 14, P = 0.03, R^2 = 0.25) involved type of nest and its interaction with orientation.

	β	STANDARD ERROR	WALD	*P*
All nests			7.37	0.03
Sheltered ledge	−2.37	1.02	5.43	0.02
Open ledge	−1.96	0.88	4.93	0.03
Nest by orientation			7.95	0.79
Sheltered ledge toward north	21.20	17 974.84	0.00	0.99
Sheltered ledge toward northeast	21.20	17 974.84	0.00	0.99
Sheltered ledge toward east	1.61	1.37	1.39	0.24
Sheltered ledge toward southeast	21.20	16 408.71	0.00	0.99
Sheltered ledge toward south	21.20	12 118.64	0.00	0.99
Sheltered ledge toward southwest	21.20	23 205.42	0.00	0.99
Sheltered ledge toward west	21.20	16 408.71	0.00	0.99
Open ledge toward northeast	20.80	15 191.52	0.00	0.99
Open ledge toward east	20.80	20 096.49	0.00	0.99
Open ledge toward south	2.13	0.88	5.86	0.01
Open ledge toward southwest	1.32	0.81	2.66	0.10
Open ledge toward west	0.51	1.06	0.23	0.63
Constant	2.37	0.60	15.37	<0.01
Residual deviance	105.57			

N = 58). The percentage of pairs initiating reproduction was 79.46%. The number of pairs per colony ranged from 2–18 ($\bar{x}$ = 6.88, SD = 5.45, N = 16).

All the colonies were located on cliffs over 40 m high ($\bar{x}$ = 131.67 m, SD = 74.06, range = 40–320 m), between 645 and 1150 masl ($\bar{x}$ = 850.56, SD = 139.80). The mean distance from nearest colony was 5523.72 m (SD = 7743.66, range = 325–24 000 m). The mean distance from the highest nest to the top of cliff 32.45 m (SD = 31.11, range = 10–120 m), and the distance from the lowest nest to the base of the cliff was 43.45 m (SD = 24.91, range = 10–80 m).

The location of the nests was as follows: open ledge, 55 nests; sheltered ledge, 26 nests; cave, 19 nests (N = 100). The nest orientations were mostly south (33.33%, N = 33) and southwest (25.25%, N = 25). Breeding pairs were comprised of: adult-adult (24.11%, N = 27), at least one adult (28.57%, N = 32), adult-subadult (8.93%, N = 10), at least one subadult (4.46%, N = 5), subadult-subadult (1.79%, N = 2), and unknown age (32.14%, N = 36). The mean distance to the nearest nest inside the colony was 72.93 m (SD = 99.54, range = 4–498 m).

Our results indicated that the nesting distribution of griffons in Castellón province has expanded in recent years. The species now occupies two new nesting colonies located 41 and 64 km southwest from the previously-reported distribution in 1999 (Del Moral and Martí 2001), which implies an increase of 64 km² (Fig. 1).

No statistical relationship was found between the cliff variables (Table 1) and productivity or breeding success for each colony. There was a significant relationship between the distance to nearest-neighbor nest and nest success in the logistic regression analysis (P = 0.014).

Using nest-site characteristics, two significant variables were involved in the model that best explained the probability of breeding successfully: type of nest and its interaction with orientation (Table 2). The probability of nest success decreased with nests located on open ledges and on sheltered ledges, and increases in success with nests inside caves. Also those nests located on open ledges and oriented to the south had a greater probability of producing a chick.

DISCUSSION

The number of nesting colonies in the Castellón province has increased from 14 in 1999 (Del Moral and Martí 2001) to 18 in 2002. However, the number of isolated pairs decreased from five to two. Productivity (0.66 chicks/pair) and breeding success (0.83 chicks/laying pair) were lower and higher, respectively, than that observed in 1999 (productivity = 0.80, breeding success = 0.81). These small differences could be due to a more thorough monitoring of the population in 2002, with a mean of 3.6 visits per colony compared to 2.6 visits made during the last census. More complete monitoring may have allowed for the detection of a greater number of nest failures (Martínez et al. 1997).

We could not make direct comparisons of reproductive parameters among regions because of different methodologies (Donázar et al. 1988, Arroyo et al. 1990, Leconte and Som 1996, Martínez et al. 1997, Olea et al. 1999). However, the breeding success found in the Castellón province (0.83 chicks/laying pair) was similar to that estimated for the Cantabrian Mountains (0.84; Arroyo et al. 1990) and for the Navarre pre-Pyrenees (0.86; Donázar et al. 1988). Also, the breeding success estimated during this study was higher than the breeding success found in the Spanish Pyrenees (0.77; Arroyo et al. 1990), French Pyrenees (0.76; Leconte and Som 1996), and the Hoces del Duratón (0.63–0.68; Palacín et al. 1993). The productivity in the study area (0.66 chicks/detected pair) was close to that reported for other Spanish territories (e.g., Extremadura = 0.67, Murcia = 0.64, Euskadi = 0.67) and was also near the national mean (0.69; Del Moral and Martí 2001).

The expansion of the species' distribution toward the southwest of the previously known range in the province (Del Moral and Martí 2001) was documented during this study. The two new colonies were probably established recently, and we found the southernmost one in 2002. This area was surveyed exhaustively for the Peregrine Falcons (*Falco peregrinus*) over the past 20 yr (Verdejo 1991, 1994, Gil-Delgado et al. 1995) and no griffon colonies were detected previously. These two new colonies, along with the previously-documented colonies, lie geographically in the western and northern portions of the province (Fig. 1). This distribution corresponds with lower human-density zones where the agrarian and livestock-related activity is still present (CAPA 1999, García-Rippolés et al. 2004). We suggest that this southward expansion may aid in the species' recovery and compensate for those locations where the species was extirpated, such as the northern portion of Valencia province (Urios et al. 1991). It is notable that 91.66% of the reproductive individuals in the two new colonies are adults (N = 11 pairs). Only one breeding pair formed by subadult-plumage individuals was recorded and they failed in their nesting attempt. This proportion matches that recorded in a northern region of Spain in a 1997 (Olea et al. 1999), where 92% were adults (N = 38).

The percentage of adults composing breeding pairs (61.61%, N = 69) in the study area was lower than that of other Spanish peninsular territories such as the West Pyrenees (75%), the Castilla Meseta (72.2%), Extremadura (72.7%), and Cádiz (73.1%; Blanco and Transverso 1996). We also noted the low proportion of two-subadult breeding pairs (1.79%) was only comparable to Castilla Meseta (3.3%; Blanco and Transverso 1996).

Our results from the logistic-regression analysis showed that the probability of raising a chick was related to the type of nest and its orientation. Age of breeding pairs was not related to the probability of nest success. To a lesser extent, the logistic model indicated a positive relationship between south-oriented nests located on open ledge and the probability of success. In our study area, this may have resulted in a higher probability of success because these sites were less exposed to the Mediterranean winter and thus, inclement weather. For the same reason, as was suggested by Elosegui (1989), nests located in caves probably had a higher probability of supporting a successful nest. Nevertheless, Donázar (1993) argued that there was generally no preference for a specific nest orientation by griffons, and that patterns observed were likely dictated by mountain range orientation.

The Eurasian Griffon is mostly a colonial nesting bird (Cramp and Simmons 1980, Donázar 1993). This likely is related to the spatial distribution of the species' food resources (Horn 1968, Donázar 1993). The unpredictable nature of the availability of carrion has been proposed as the main factor favoring this behavior (Donázar 1993). In our study, this was supported by the negative relationship observed between the distance to the nearest-neighbor nest in the same colony and its success. We suggest that the carrion availability in our study area was unpredictable, and that the number of permanent functioning "vulture restaurants" were few. This unpredictability of food resources may explain why these colonies exhibiting greater nest aggregation have the highest reproductive performance in our province. We suggest that the colonies might act as effective information centers

(Ward and Zahavi 1973). In addition, the colonial habit could also reduce the predatory risk by Common Ravens (*Corvus corax*; Elosegui 1989).

Factors like the increasing of livestock-trophic resources, the recovery of wild fauna, the creation of vulture restaurants, and the lessening of direct and indirect prosecution of the species by humans in recent years (Donázar 1993), probably has fostered the species' range expansion. Moreover, due to "mad-cow" disease in Europe in 1999 (García-Rippolés et al. 2004), the National Spanish Government prohibited the *ad hoc* dumping of carcasses in an attempt to prevent any possible effects on scavengers. New national laws concerning the establishment of "vulture restaurants," and successive cases of livestock diseases, might have eliminated the access to previously available food resources to carrion-eating birds. This reduction in food availability may have helped to stimulate southward range expansion by Eurasian Griffons in the Castellon province.

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